A Linear Control Toolbox - towards simple LPV control

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1 Abstract

Since the early days of control, a wide variety of control techniques has emerged, one of them being the $\mathscr{H}_\infty$ / $\mathscr{H}_2$ framework. Although its practical value has been proven many times over in academia, industry seems reluctant to adopt this design paradigm. This observation inspired the development of a matlab control toolbox, known as the LTI toolbox, which facilitates the design and analysis of $\mathscr{H}_\infty$ and $\mathscr{H}_2$ controllers as described by [4].

An additional advantage of the $\mathscr{H}_\infty$ / $\mathscr{H}_2$ framework is that it naturally extends to Linear Parameter Varying control. The LPV paradigm holds the middle ground between the restricted class of LTI systems and the general class of nonlinear systems. This property makes LPV control an ideal stepping stone to get nonlinear control adopted by industry. Some steps in the direction of user-friendly software have been made. Examples hereof are Matlab simulink [3] and LPVtools [2] which are both capable of LPV controller synthesis with polynomial parameter dependency.

This paper focusses on the extension of the aforementioned LTI toolbox towards LPV controller design, making it a more general Linear Control Toolbox[1]. The main driver is to support the recent developments in LPV controller design, based on BSplines as described by [1]. Additionally, the use of BSpline parameters does not exclude a polynomial parameter dependency. This allows the Linear Control Toolbox to serve as a front-end for polynomial-based solvers.

2 LPV controller design

The Linear Control Toolbox provides a custom SystemParameter class which represents a parameter and carries information needed for LPV modeling. The classic LPV design assumes that the parameter lies in a domain which is characterized by bounds on the parameter and its rate of variation.

Code example 1 shows the basic usage of the SystemParameter. First the bounds on the parameter and its rate of variation are declared. Next the parameter, p, is defined as a SystemParameter based on the previously stated bounds. Subsequently, the state-space matrices are constructed using p.

```
Pbound = [0.2 0.8];      % parameter bounds
DPbound = [-0.02,0.03]; % rate bounds
p = SystemParameter(Pbound,DPbound);

A = [-p,0;p^2,-1];
B = [1;0];
C = [1,1];
D = [0];

G = SSsys(A,B,C,D);
```

Code example 1: Linear Control Toolbox code to create an LPV system.

Classical approaches assume a polynomial dependency of the state-space model on the parameter p, as the solvers rely on Pólya relaxations or Sum-of-Squares. However, recent developments have shown the applicability of BSplines. These provide a more general formulation of the parameter dependency which is the main reason to use them in this work[2].

In a second step, the system G is used by the Linear Control Toolbox to synthesize a BSpline parametrized LPV controller. The signal-based syntax remains unchanged with respect to the former LTI toolbox [4].

References

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[1] The Linear Control Toolbox can be found here: `https://github.com/meco-group/lti_toolbox`.

[2] The used matlab spline toolbox can be found here: `https://gitlab.mech.kuleuven.be/meco/splines-m`.